

# Modeling Economic Growth

*Presentation to the*  
**Kentucky Council on Post-Secondary Education**  
**June 3<sup>rd</sup>, 2015**

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**Kentucky Energy and Environment Cabinet**  
502-564-7192

This Presentation is Available Online at:

<http://1.usa.gov/1BIR4Qm>

## Overview

**Purpose:** This model estimates the implications of increasing electricity prices for economic growth, measured in terms of employment and value added by economic sector.

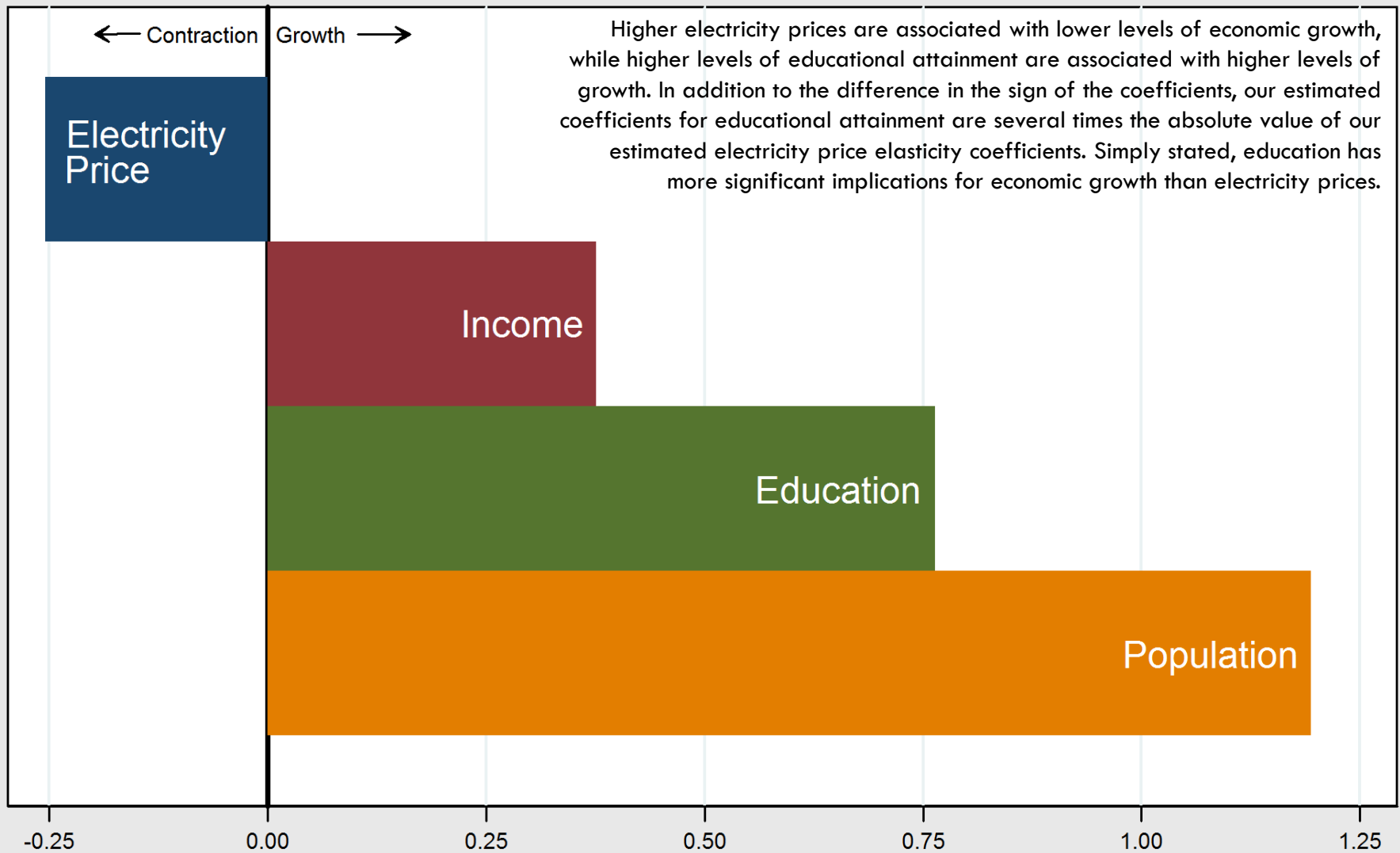
**Findings:** A hypothetical 10% increase in the real price of electricity nationally would be associated with a decrease of one million jobs and \$142 billion in Gross Domestic Product (GDP). However, impacts will vary substantially by industry, with electricity-intensive manufacturing experiencing the most-significant losses of productive capacity.

**What does this have to do with education?** In order to identify our relationship of interest, we had to first account for the differences in educational attainment between states and years. We found education to be a more significant determinant of economic growth than electricity prices for most industries. We estimate that a 10% increase in bachelor degree attainment across the United States would increase total employment by 7.7 million jobs and GDP by \$447 billion annually.

**Statistical Modeling Details:** We estimated separate multiple regression of panel data models using fixed effects by state for employment and value added for 12 specific economic sectors for a total of 24 models. Models were estimated using public data.

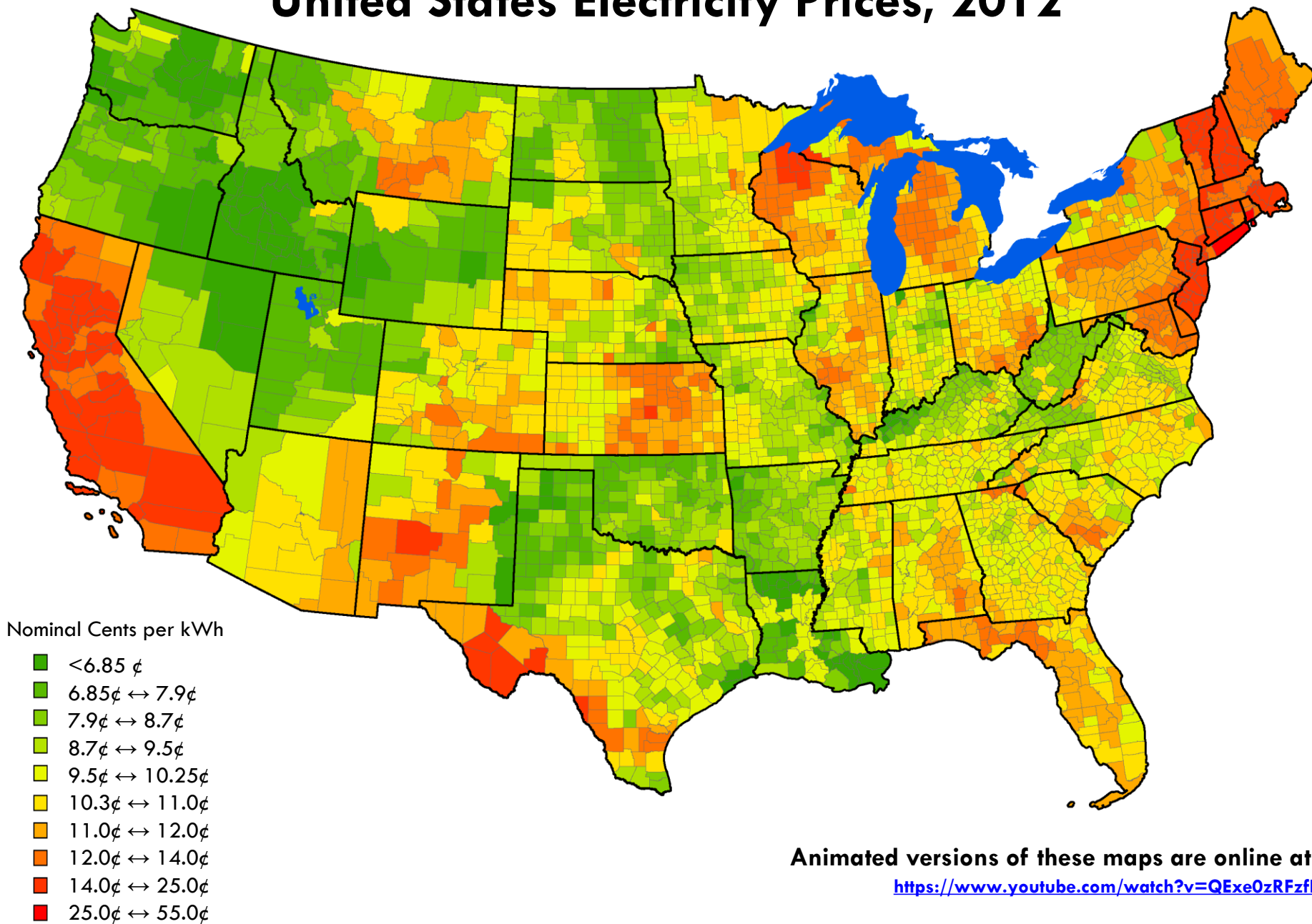
**Programmatic Details:** This project received no funding beyond staff time. Models and forecasts were estimated using Stata 11 SE software, but identical models could have been estimated in R or any professional data modeling software.

## Correlates of Economic Growth

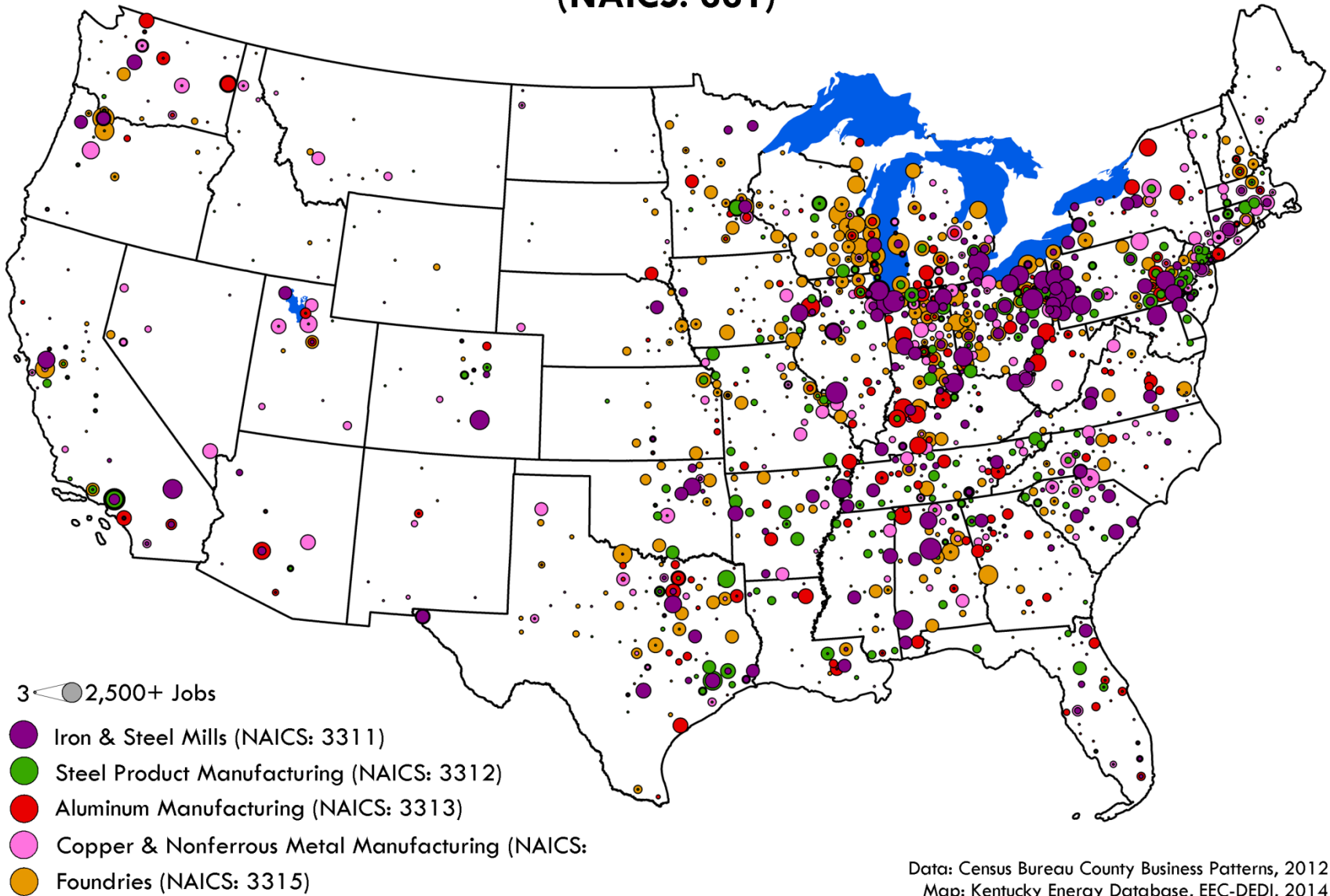


Kentucky Energy Database, EEC-DEDI, 2015

# United States Electricity Prices, 2012



# United States Primary Metal Manufacturing Employment, 2012 (NAICS: 331)





CENTURY ALUMINUM SEBREE LLC  
SPLR ID  
SPLR ASG (130) 174717525  
LOT 413  
SERIAL # (S) 159-000837  
PRODUCED IN KENTUCKY, USA  
STORAGE TAG

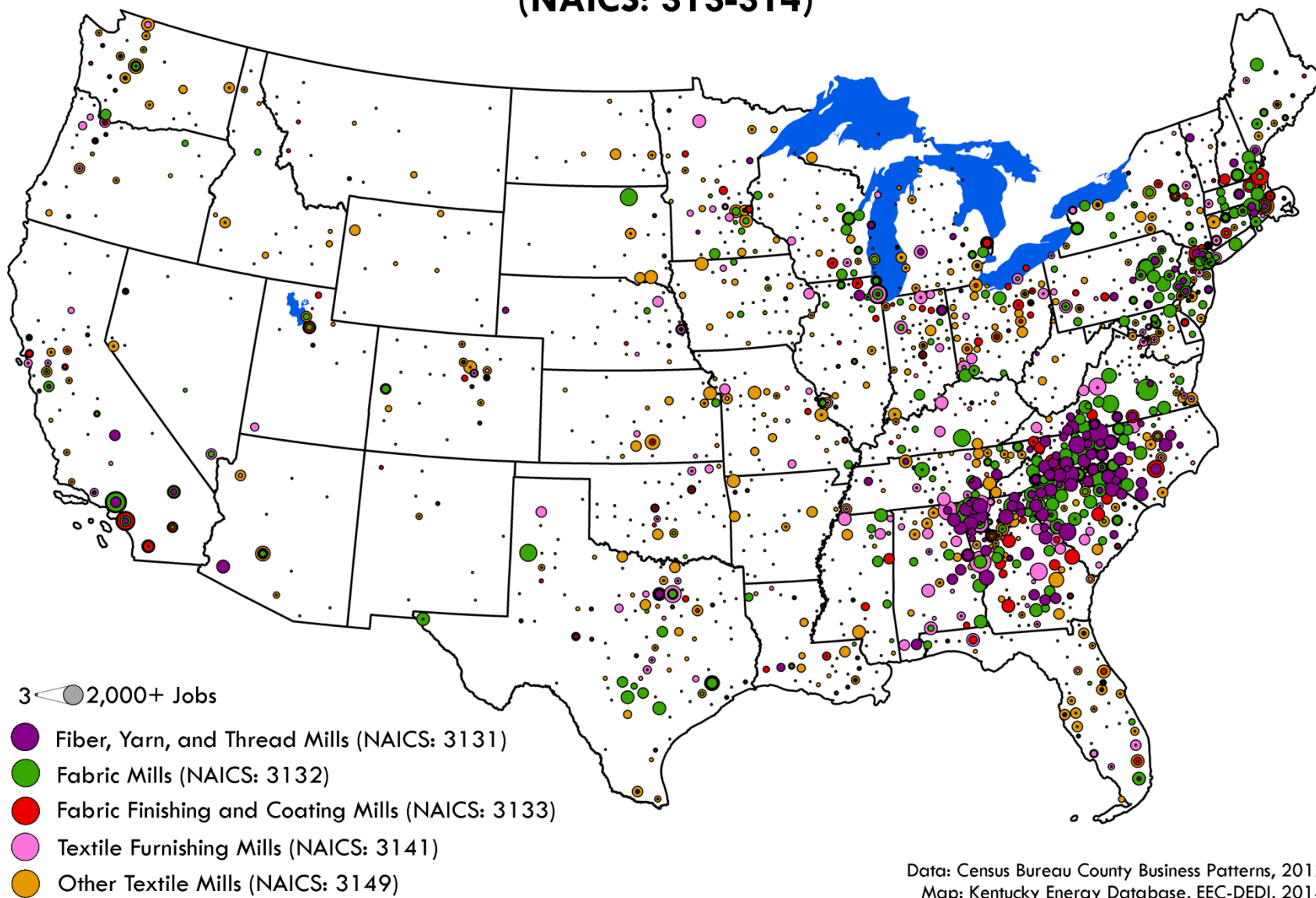
Aron & Adam touring Century Aluminum in Sebree, Kentucky in 2015



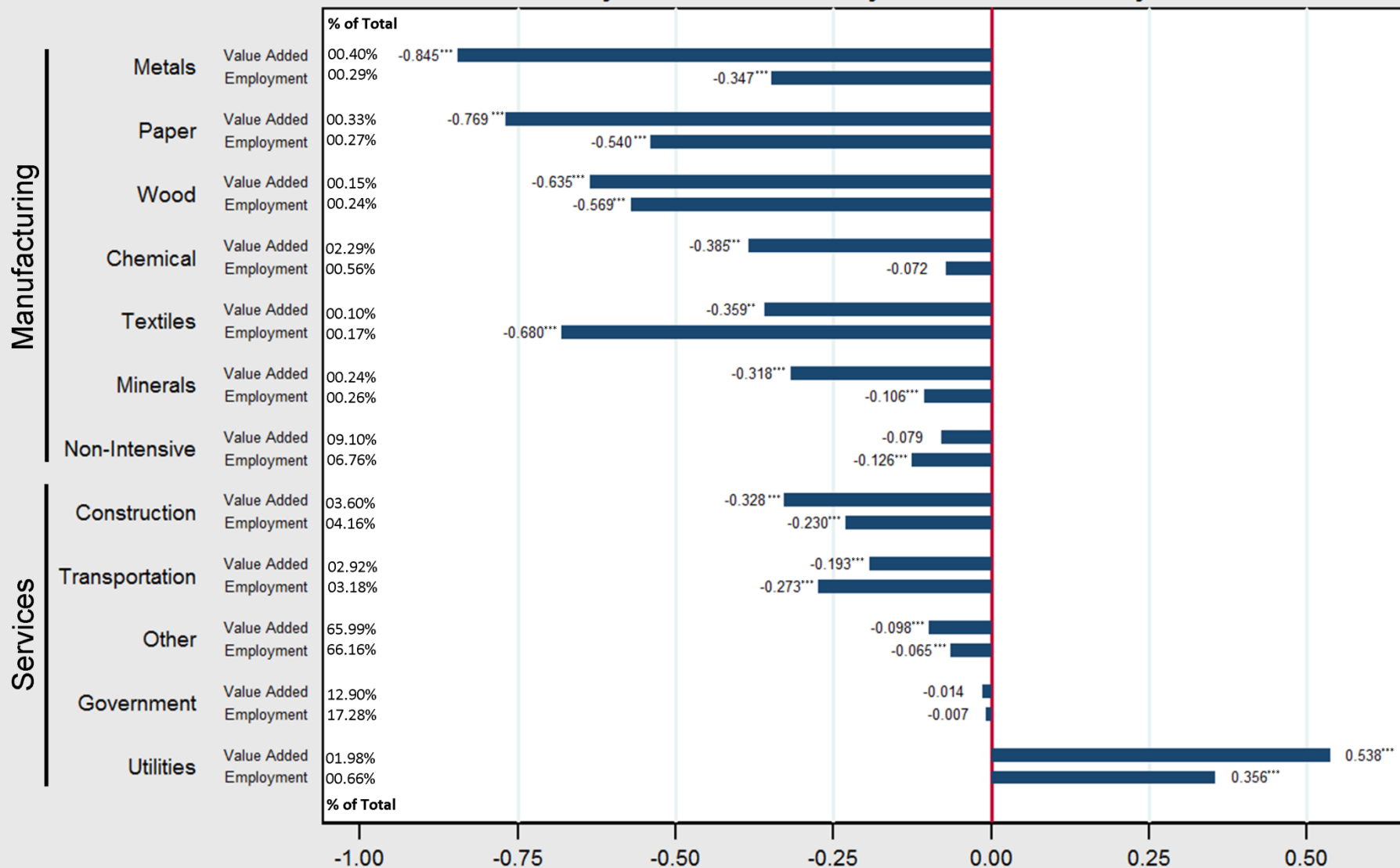
Aron & Adam touring Century Aluminum in Sebree, Kentucky in 2015



# United States Textile Manufacturing Employment, 2012 (NAICS: 313-314)



# Electricity Price Elasticity Coefficients by Sector

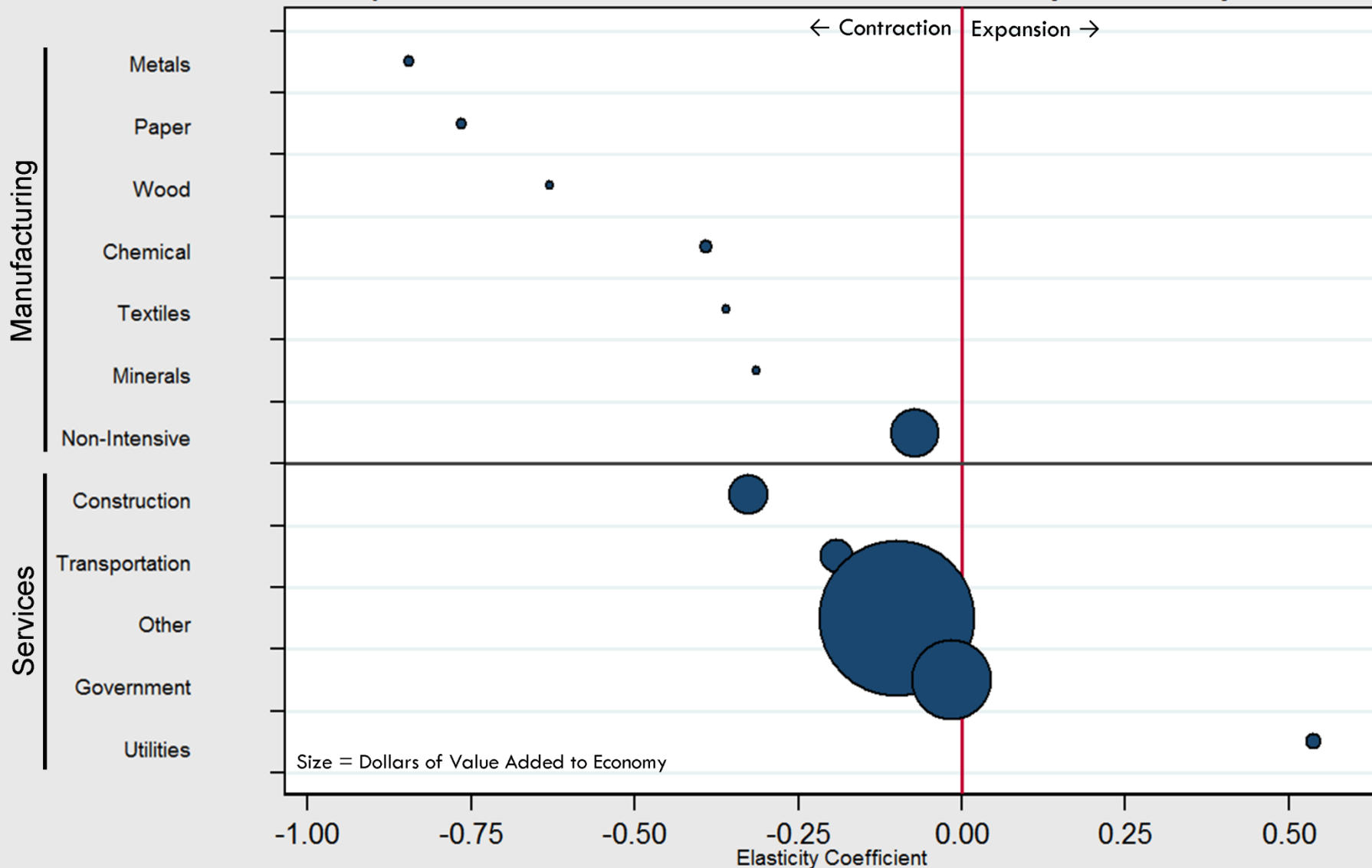


Kentucky Energy Database, EEC-DEDI, 2014

Elasticity Coefficient

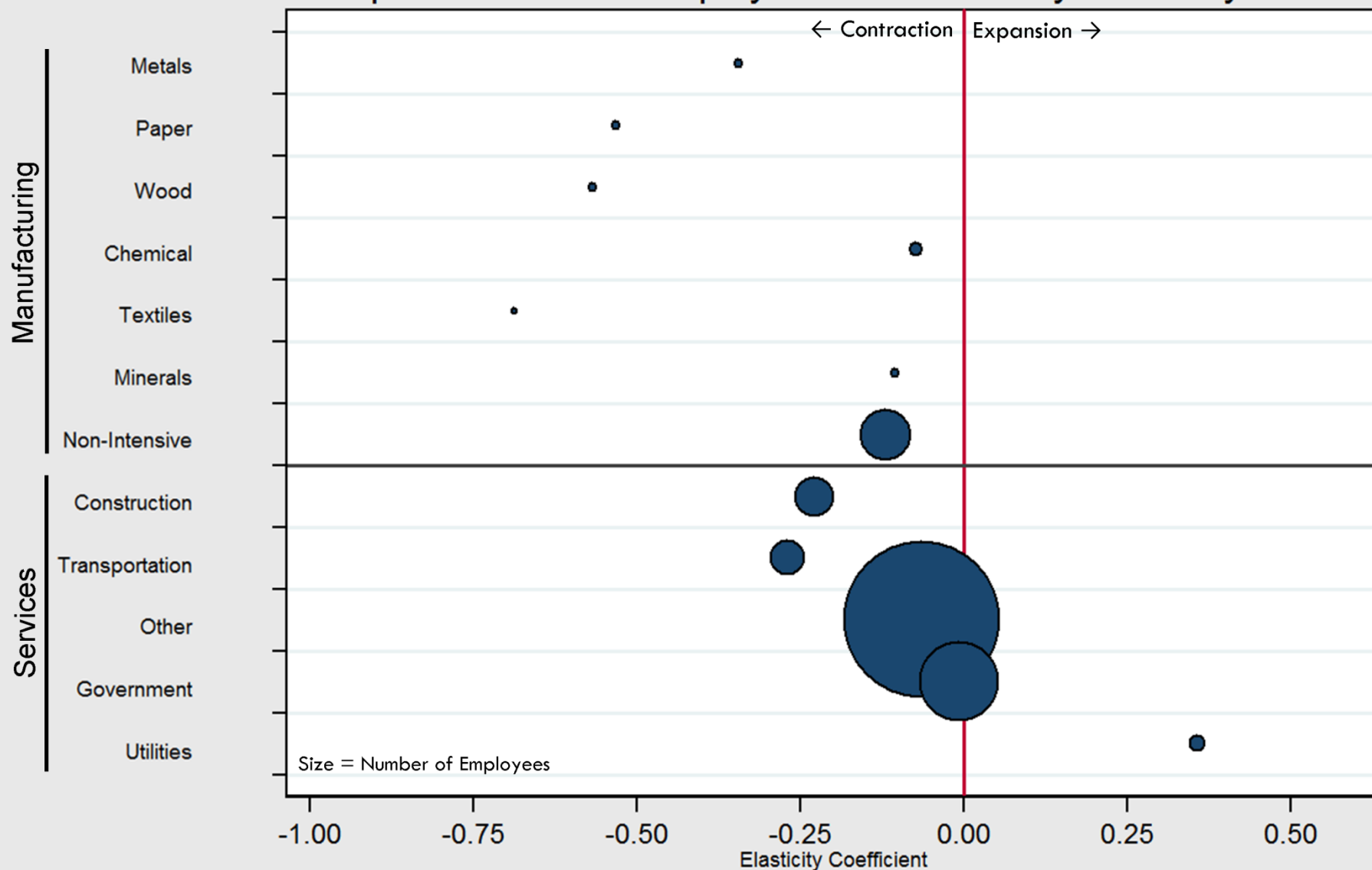
Asterisk Denotes Statistical Significance at the Following Levels: \*  $P > |t| < 0.05$ , \*\*  $P > |t| \leq 0.01$ , \*\*\*  $P > |t| \leq 0.001$

## Responsiveness of Value Added to Electricity Prices by Sector



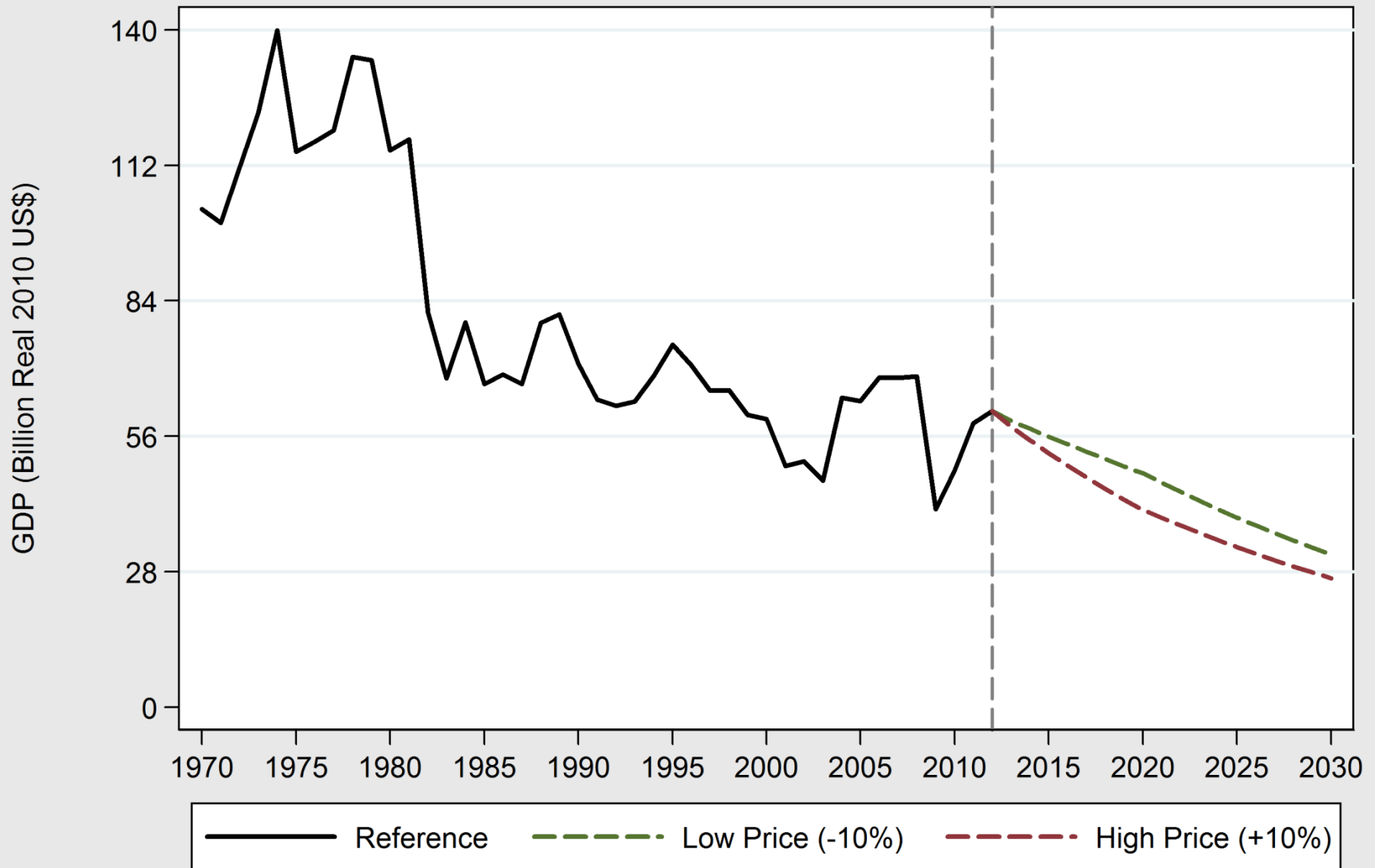
Kentucky Energy Database, EEC-DEDI, 2014

## Responsiveness of Employment to Electricity Prices by Sector



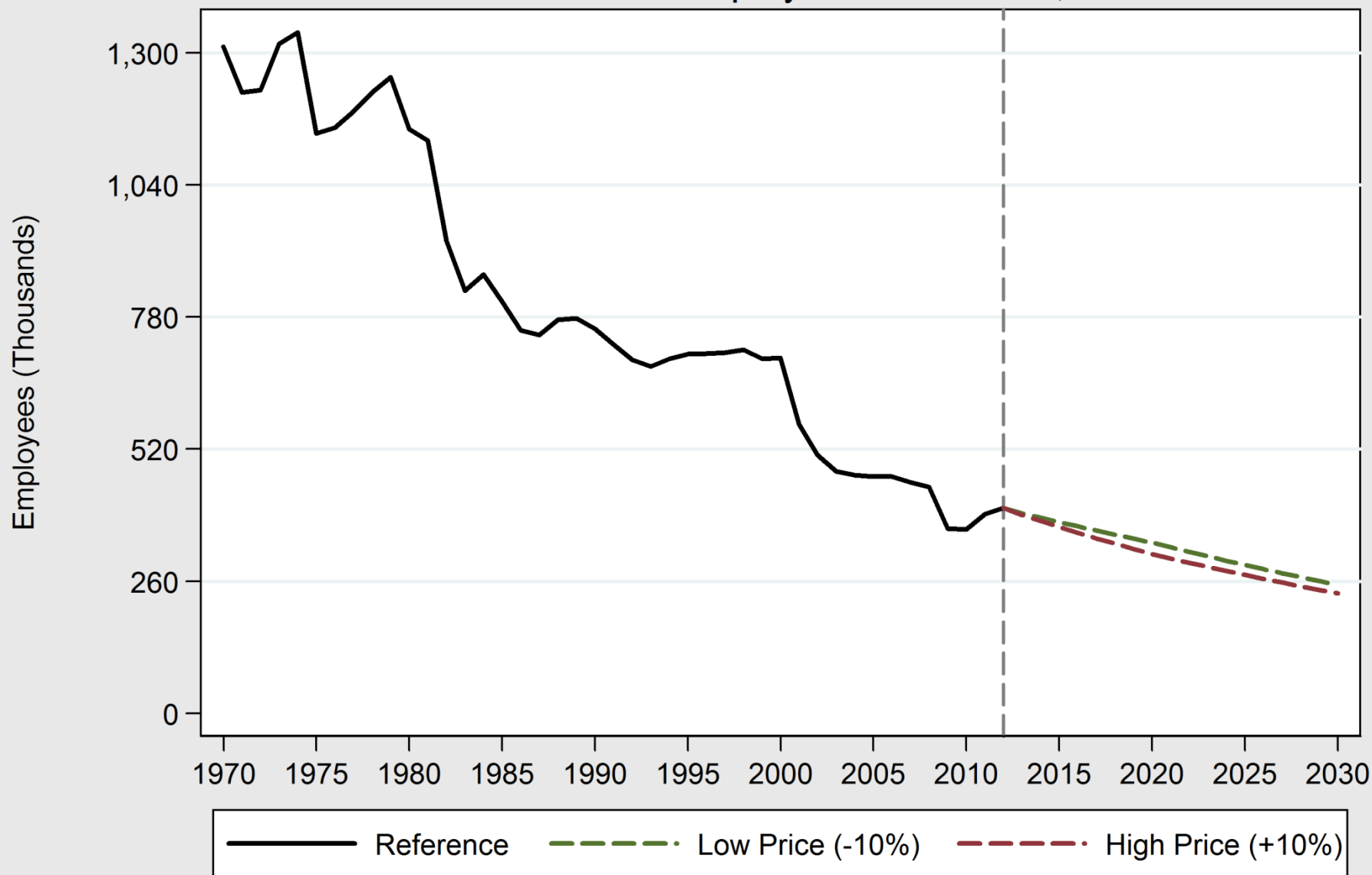
Kentucky Energy Database, EEC-DEDI, 2014

## United States Metals Real GDP Forecast, 1970-2030



Kentucky Energy Database, EEC-DEDI, 2014

## United States Metals Employment Forecast, 1970-2030



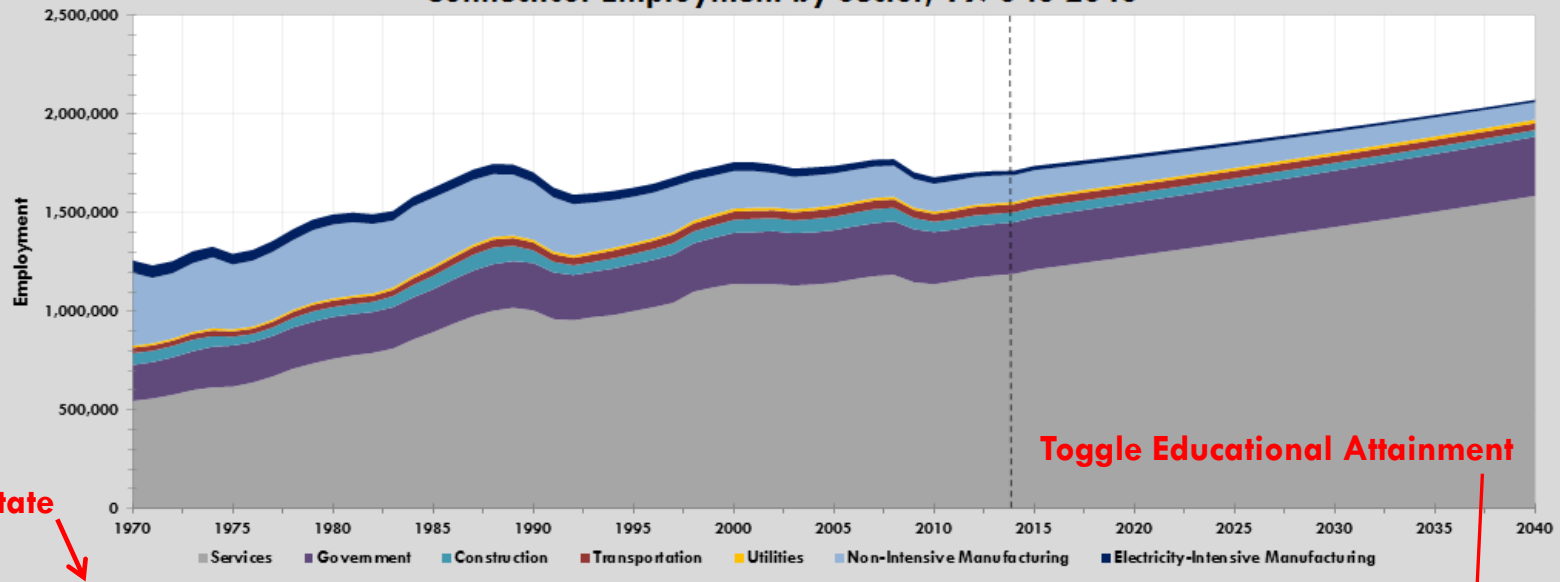
Kentucky Energy Database, EEC-DEDI, 2014

# Interactive Excel Visual Basic Version

Download the Excel VBA interactive version of this model at:

<http://1.usa.gov/1G31BuN>

# Connecticut Employment by Sector, 1970 to 2040



Select a State

Select a State

Connecticut

Extrapolate

Zero Growth

Manual Entry

Model Input Assumption				
2025 Electricity Price (Real 2010 \$US per kWh)	2025 Petroleum Prices (Real 2010\$ per MMBTU)	2025 Connecticut Population	2025 Per Capita Personal Income (Real 2010 \$US)	2025 % of Population with Bachelor's Degree
\$0.2245	\$29.5184	3,811,502	\$61,016.74	43.96%
Electricity Price AGR	Petroleum Price AGR	Population AGR	Personal Income AGR	Educational Attainment AGR
3.357%	0.428%	0.428%	0.496%	1.50%

2000-2011 Average Growth

2000-2011 Average Growth

1997 to 2011 Linear Trend

2003 to 2011 Linear Trend

15% Annual Growth

Employment by Sector	2012	2025
Total Employment	1,706,622	1,859,805
Other Services	1,173,510	1,354,029
Government	260,741	278,762
Non-Intensive Manufacturing	141,388	113,843
Construction	53,356	43,006
Transportation	41,912	38,488
Utilities	11,684	14,413
Chemical Manufacturing	11,346	9,654
Metal Manufacturing	3,863	1,962
Paper Manufacturing	3,563	2,225
Minerals Manufacturing	2,240	1,444
Textiles Manufacturing	1,821	1,299
Wood Manufacturing	1,198	680

Instructions About Model

Explore Model

View & Edit Model Coefficients

Connecticut Electricity-Intensive Manufacturing Employment

Chemical

Metal

Paper

Minerals

Textiles

Wood

0 2,000 4,000 6,000 8,000 10,000 12,000

■ 2012 ■ 2025

Explore component calculations. . .

# **Statistical Appendix**

# Analytical Methodology

A multiple regression of panel data model using fixed effects was estimated for employment and value added by economic sector for a total of 24 models. Fixed effects were used to control for the numerous factors inherently affecting sector-specific employment as well as electricity prices from state to state that have not been accounted for in the independent variables included in this study.

The multiple regression of panel data model with fixed effects can be generally given by,

$$Y_{it} = \beta_0 + \sum_{j=1}^{k-1} \beta_j X_{jit} + \alpha_i + \varepsilon_{it}$$

Where  $i$  and  $t$  index states and years, such that  $y_{it}$  is the dependent variable of interest, employment by industry, in state  $i$  in year  $t$ ,  $\beta_0$  is the constant  $y$  intercept across all states,  $X$  is a  $k$  by 1 vector of explanatory variables,  $\beta_j X_{jit}$  is the product of the observation for each independent variable  $j$  through  $k$  for state  $i$  in year  $t$  and the coefficient of  $X$ ,  $k$  is the total number of included independent variables,  $\alpha_i$  is the time-invariant fixed effect for state  $i$ , and  $\varepsilon_{it}$  are the residuals, and where  $\varepsilon_{it} \sim N(0, \sigma^2)$ , or are approximately normally distributed with a mean of zero.

# Analytical Methodology

A multiple regression of panel data model using fixed effects was estimated for employment and value added by economic sector for a total of 24 models. Fixed effects were used to control for the numerous factors inherently affecting sector-specific employment as well as electricity prices from state to state that have not been accounted for in the independent variables included in this study.

The multiple regression of panel data model with fixed effects can be generally given by,

Predicted Employment by Industry in State (i) and Time (t)

$$Y_{it} = \beta_0 + \sum_{j=1}^{k-1} \beta_j X_{jit} + \alpha_i + \varepsilon_{it}$$

Diagram illustrating the components of the fixed effects regression model:

- $Y_{it}$ : Predicted Employment by Industry in State (i) and Time (t)
- $\beta_0$ : Constant Intercept Across States
- $\sum_{j=1}^{k-1} \beta_j X_{jit}$ : Sum of the product of the observation for each independent variable  $j$  through  $k$  for state  $i$  in year  $t$  and the coefficient of  $X_j$
- $\alpha_i$ : Fixed Effect for State (i)
- $\varepsilon_{it}$ : Stochastic Error Term ( $\sim N(0, \sigma^2)$ )

Where  $i$  and  $t$  index states and years, such that  $y_{it}$  is the dependent variable of interest, employment by industry, in state  $i$  in year  $t$ ,  $\beta_0$  is the constant  $y$  intercept across all states,  $X$  is a  $k$  by 1 vector of explanatory variables,  $\beta_j X_{jit}$  is the product of the observation for each independent variable  $j$  through  $k$  for state  $i$  in year  $t$  and the coefficient of  $X_j$ ,  $k$  is the total number of included independent variables,  $\alpha_i$  is the time-invariant fixed effect for state  $i$ , and  $\varepsilon_{it}$  are the residuals, and where  $\varepsilon_{it} \sim N(0, \sigma^2)$ , or are approximately normally distributed with a mean of zero.

# Complete Model of Employment & Value Added by Sector

Logged Variables		Manufacturing														Services									
		Metals		Paper		Wood		Chemical		Textiles		Minerals		Non-Intense		Construct		Transport		Other		Government		Utilities	
		V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp
Electricity Price	$\beta_1$	-0.845	-0.347	-0.769	-0.540	-0.635	-0.569	-0.385	-0.072	-0.359	-0.680	-0.318	-0.106	-0.079	-0.126	-0.328	-0.230	-0.193	-0.273	-0.098	-0.065	-0.014	-0.007	0.538	0.356
	SE	0.089	0.064	0.091	0.064	0.059	0.041	0.062	0.051	0.124	0.114	0.039	0.031	0.045	0.034	0.025	0.023	0.022	0.020	0.015	0.008	0.010	0.008	0.028	0.022
	P> t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.154	0.004	0.000	0.000	0.001	0.079	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.159	0.330	0.000	0.000
Personal Income	$\beta_2$	0.427	-0.254	0.078	-1.160	0.042	-0.042	1.284	0.408	-0.870	-1.246	1.838	0.772	-0.058	-0.775	2.582	1.577	0.762	0.081	1.269	0.220	0.638	0.059	0.093	-0.004
	SE	0.219	0.157	0.223	0.157	0.146	0.100	0.152	0.124	0.305	0.280	0.096	0.076	0.110	0.084	0.060	0.057	0.054	0.050	0.037	0.019	0.024	0.019	0.069	0.053
	P> t	0.052	0.106	0.727	0.000	0.774	0.677	0.000	0.001	0.004	0.000	0.000	0.000	0.601	0.000	0.000	0.000	0.000	0.107	0.000	0.000	0.000	0.001	0.178	0.933
Education	$\beta_3$	1.589	0.839	2.586	1.459	3.392	2.449	0.238	0.646	-1.657	-0.413	0.199	0.305	0.504	1.077	-0.037	0.101	0.278	0.607	0.314	0.618	-0.174	0.147	0.756	0.411
	SE	0.195	0.140	0.198	0.140	0.130	0.089	0.136	0.111	0.271	0.250	0.085	0.068	0.098	0.075	0.054	0.051	0.048	0.045	0.033	0.017	0.022	0.017	0.061	0.047
	P> t	0.000	0.000	0.000	0.000	0.000	0.000	0.079	0.000	0.000	0.098	0.019	0.000	0.000	0.000	0.496	0.049	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Population	$\beta_4$	0.863	0.763	2.136	2.190	0.704	0.301	0.509	0.696	1.417	2.003	1.511	1.403	1.687	1.444	1.387	1.290	1.159	1.235	1.118	0.940	0.650	0.665	0.989	0.820
	SE	0.115	0.082	0.117	0.083	0.077	0.053	0.080	0.065	0.160	0.147	0.050	0.040	0.058	0.044	0.032	0.030	0.029	0.026	0.019	0.010	0.013	0.010	0.036	0.028
	P> t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Petroleum Price	$\beta_5$	0.399	-0.101	-0.240	-0.223	-0.226	-0.192	0.104	-0.059	-0.368	-0.114	0.033	-0.045	-0.112	-0.191	0.105	-0.003	0.058	-0.098	0.061	-0.068	-0.019	-0.041	-0.248	-0.129
	SE	0.050	0.036	0.051	0.036	0.033	0.023	0.035	0.028	0.069	0.064	0.022	0.017	0.025	0.019	0.014	0.013	0.012	0.011	0.008	0.004	0.006	0.004	0.016	0.012
	P> t	0.000	0.005	0.000	0.000	0.000	0.000	0.003	0.037	0.000	0.074	0.124	0.009	0.000	0.000	0.000	0.825	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Year	$\beta_6$	-144.2	-81.3	-161.2	-85.3	-193.8	-134.9	-6.3	-48.9	87.4	13.0	-96.0	-78.1	-28.6	-60.9	-68.8	-46.7	-29.4	-24.2	-14.5	-3.7	22.6	0.3	-7.8	-12.0
	SE	10.76	7.69	10.92	7.70	7.16	4.91	7.47	6.10	14.95	13.74	4.70	3.72	5.41	4.12	2.96	2.81	2.67	2.47	1.81	0.93	1.20	0.91	3.38	2.61
	P> t	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.02	0.00	
Constant ( $\beta_0$ )	$\beta_0$	1080	615	1192	633	1459	1024	34	364	-665	-105	694	572	201	458	484	330	206	174	90	24	-178	-1	49	86
	SE	79.6	56.9	80.9	57.0	53.0	36.3	55.3	45.1	110.6	101.7	34.8	27.5	40.0	30.5	21.9	20.8	19.8	18.2	13.4	6.9	8.9	6.7	25.0	19.3
	P> t	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.05	0.00	
N		2192	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2192	2193	2193	2193	2193	2193
R <sup>2</sup> Within		0.145	0.262	0.191	0.305	0.394	0.441	0.504	0.072	0.128	0.134	0.365	0.451	0.435	0.422	0.910	0.761	0.751	0.787	0.951	0.979	0.961	0.915	0.711	0.549
R <sup>2</sup> Between		0.578	0.653	0.583	0.645	0.121	0.019	0.642	0.692	0.520	0.521	0.836	0.839	0.897	0.869	0.957	0.951	0.853	0.946	0.983	0.986	0.883	0.928	0.904	0.905
R <sup>2</sup> Overall		0.540	0.621	0.550	0.626	0.140	0.034	0.556	0.669	0.472	0.481	0.812	0.824	0.866	0.852	0.932	0.930	0.845	0.934	0.976	0.986	0.881	0.926	0.887	0.891

# Electricity Intensity of United States Manufacturing, 2010

NAICS	Description	Electricity Intensity Rank	Electricity Intensity (kWh/\$)	Electricity Intensity Range (kWh/\$)	Total Employees (US)	Electricity Consumed (TWh)	Value of Product (Billion \$)
Intensive	<b>Electricity-Intensive Total</b>	--	<b>0.530</b>	<b>0.011 ↔ 5.829</b>	<b>1,479,071</b>	<b>313.202</b>	<b>590.986</b>
	322 Paper Manufacturing	1	0.646	0.195 ↔ 1.501	351,931	109.771	169.954
	331 Primary Metal Manufacturing	2	0.560	0.059 ↔ 5.829	353,671	129.524	231.185
	313 Textile Mills	3	0.453	0.123 ↔ 0.506	107,661	13.183	29.109
	327 Nonmetallic Mineral Product Manufacturing	4	0.422	0.011 ↔ 1.854	336,216	38.349	90.781
	321 Wood Product Manufacturing	5	0.320	0.053 ↔ 0.957	329,592	22.375	69.957
	325 Chemical Manufacturing	6	0.292	0.038 ↔ 2.887	703,280	204.749	701.230
Non-Intensive	<b>Non-Intensive Total</b>	--	<b>0.120</b>	<b>0.021 ↔ 2.887</b>	<b>9,088,286</b>	<b>436.645</b>	<b>3,624.430</b>
	326 Plastics And Rubber Products Manufacturing	7	0.288	0.125 ↔ 0.621	664,641	54.331	188.583
	323 Printing And Related Support Activities	8	0.178	0.145 ↔ 0.181	468,030	14.667	82.488
	314 Textile Product Mills	9	0.151	0.145 ↔ 0.641	108,934	3.295	21.818
	311 Food Manufacturing	10	0.150	0.026 ↔ 0.736	1,364,157	97.125	646.451
	332 Fabricated Metal Product Manufacturing	11	0.146	0.062 ↔ 0.398	1,242,904	43.157	295.187
	335 Electrical Equipment and Appliances	12	0.115	0.055 ↔ 0.558	327,441	12.714	110.993
	324 Petroleum And Coal Products Manufacturing	13	0.111	0.045 ↔ 0.182	99,225	69.689	627.572
	337 Furniture And Related Product Manufacturing	14	0.104	0.036 ↔ 0.171	332,316	6.094	58.795
	334 Computer And Electronic Product Manufacturing	15	0.090	0.021 ↔ 0.268	836,475	30.611	340.683
	336 Transportation Equipment Manufacturing	16	0.086	0.029 ↔ 0.346	1,181,363	54.540	633.275
	315 Apparel Manufacturing	17	0.083	0.028 ↔ 0.296	104,457	1.135	13.643
	333 Machinery Manufacturing	18	0.083	0.042 ↔ 0.213	930,290	26.310	317.694
	312 Beverage And Tobacco Product Manufacturing	19	0.082	0.046 ↔ 0.116	132,409	10.820	131.845
	316 Leather And Allied Product Manufacturing	20	0.082	0.128 ↔ 0.131	27,609	0.413	5.049
	339 Miscellaneous Manufacturing	21	0.078	0.042 ↔ 0.271	564,755	11.746	150.353

**Fortunately, the computer does most of the hard work—this is what we actually see in Stata.**

```
. dis "Primary Metal Employment"
Primary Metal Employment

. eststo emp_331_ln_fe : xtreg emp_331_ln rate_r_ln pcpi_r_ln edbdm_ip_ln_f   pop_ln patcd_
> r_ln year_ln if code!="US", fe
```

```
Fixed-effects (within) regression               Number of obs   =       2193
Group variable: code_n                         Number of groups =        51

R-sq:  within = 0.2623                          obs per group:  min =        43
        between = 0.6534                          avg =       43.0
        overall = 0.6207                          max =        43

corr(u_i, Xb) = 0.5662                          F(6,2136)       =      126.58
                                                Prob > F        =      0.0000
```

emp_331_ln	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
rate_r_ln	-.3474572	.0639314	-5.43	0.000	-.4728315	-.2220828
pcpi_r_ln	-.2535152	.1567979	-1.62	0.106	-.5610077	.0539772
edbdm_ip_ln_f	.8390695	.1396222	6.01	0.000	.5652598	1.112879
pop_ln	.7629551	.0823382	9.27	0.000	.6014836	.9244266
patcd_r_ln	-.1011384	.0355641	-2.84	0.004	-.1708824	-.0313945
year_ln	-81.26569	7.688793	-10.57	0.000	-96.34399	-66.18739
_cons	615.4862	56.90711	10.82	0.000	503.8871	727.0854
sigma_u	1.5062896					
sigma_e	.39200235					
rho	.93656919	(fraction of variance due to u_i)				

```
F test that all u_i=0:      F(50, 2136) =    296.15          Prob > F = 0.0000
```

```
. estat ic
```

Model	Obs	ll(null)	ll(model)	df	AIC	BIC
emp_331_ln~e	2193	-1362.701	-1029.138	7	2072.277	2112.128

Note: N=Obs used in calculating BIC; see **[R] BIC note**

```
. estimates store fe
```

```
. predict est_emp_331_fe, u
(8672 missing values generated)
```



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**Download the Associated White Paper:**

<http://1.usa.gov/1aVhOWu>

**Download this Presentation:**

<http://1.usa.gov/1BIR4Qm>

**Download the Excel VBA interactive version of this model at:**

<http://1.usa.gov/1G31BuN>